PATENT
Attorney Docket No. 401452/Takada

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:

AOYAGI et al.

Application No.	Unassigned	Art Unit:	Unassigned
Filed:	November 14, 2001	Examiner:	Unassigned
For:	SEMICONDUCTOR LASER DEVICE		

PRELIMINARY AMENDMENT

Commissioner for Patents
Washington, D. C. 20231

Dear Sir:

Prior to the examination of the above-identified patent application, please enter the following amendments and consider the following remarks.

IN THE SPECIFICATION:

Replace the paragraph beginning at page 1, line 5, with:

The present invention relates to a semiconductor laser device, and, more particularly, to a semiconductor laser device having a diffraction grating layer with a phase shift structure used for optical communication.

Replace the paragraph beginning at page 1, line 14, with:

A distributed feedback semiconductor laser having a diffraction grating provided in the direction of an optical waveguide effects optical feedback corresponding to the period of the diffraction grating, thus enabling single-mode emission. Thus, the distributed feedback semiconductor laser has been developed for optical communication.

Replace the paragraph beginning at page 1, line 20, with:

Japanese Patent Application Laid-Open No. Hei. 1-155677 describes an invention pertaining to a distributed feedback (DFB) semiconductor laser. In relation to a related-art DFB semiconductor laser, the positional relationship between reflection surfaces provided at both ends of the laser in the direction of an optical waveguide and the phase of the diffraction grating affects an oscillation characteristic having a single longitudinal mode. For this reason, a $\lambda/4$ phase-shifted structure has been employed, and both end surfaces of the laser are covered with a non-reflection coating, thereby minimizing the reflectance of the end faces. If the product of a coupling factor κ and a cavity length L, that is, κL, is not in the vicinity of a value of 1.25, an axial hole burning phenomenon arises, and, in turn, deteriorates a single longitudinal mode characteristic of the laser. In order to solve the problem, there is described a DFB semiconductor laser, in which the reflectance of optical power of one end surface is set to 30% and the reflectance of the other end is set to 5 to 15%, thereby achieving a κL value of $0.4 \leq \kappa L \leq 1.3$.

Replace the paragraph beginning at page 2, line 5, with:

The related-art DFB semiconductor laser induces an axial hole burning phenomenon when the product of a coupling factor κ and a cavity length L, that is, κL, is not in the vicinity of a value of 1.25, thus deteriorating a single longitudinal mode characteristic of the laser. A high-precision, non-reflection coating technique has been pursued, and there has been devised a window structure for embedding end-face sections of a waveguide for minimizing the reflectance of the end faces. In light of the above-

described drawbacks, Japanese Patent Application Laid-Open No. Hei. 2-20087 describes a DFB semiconductor laser which is comparatively easy to manufacture and has a structure capable of realizing a single longitudinal mode at high yield. The DFB semiconductor laser has one or more phase shift regions within 20% of the resonance length with reference to the center of the cavity. The reflectance of respective end faces is set to 5 to 15%, and the product κL is set to the range of $0.6 \leq \kappa L \leq 1.0$.

Replace the paragraph beginning at page 2, line 20, with:

In relation to the related-art DFB semiconductor laser, the diffraction grating is adjusted such that the product of a coupling factor κ and a cavity length L, that is, κL, assumes a value of 1.2 to 1.3. However, such a semiconductor laser involves a high oscillation threshold current and it tends to saturate in optical output more than other DFB semiconductor lasers under high-temperature operation. To solve the problem, Japanese Patent Application Laid-Open No. Hei. 2-90688 describes a λ/4 phase-shifted DFB semiconductor laser. In relation to the laser, an optical guide layer is provided between an active layer and a cladding layer, wherein the thickness of the optical guide layer changes at a period which is an integer multiple of half the wavelength of traveling light. Further, the energy gap of the optical guide layer is greater than that of the active layer and smaller than that of the cladding layer. The product of a coupling factor κ and a cavity length L, that is, κL, is set to a value of 1.5 to 2.5.

Replace the paragraph beginning at page 3, line 3, with:

In relation to the related-art DFB semiconductor laser, a multilayer dielectric film is formed on an output end face of the laser, thereby reducing optically-induced return noise. This also drastically reduces optical output from the output end face. In order to reduce the optically-induced return noise and to ensure sufficient optical output, Japanese Patent Application Laid-Open No. Hei. 5-48197/ describes a λ/4 phase-shifted DFB semiconductor laser which is constructed as follows. Namely, the output end face of the laser is covered with a non-reflective coating. Provided that a length from a rear end face

to a $\lambda/4$ phase shift point is taken as Ls and the length of a laser cavity is taken as L, $\lambda/4$ phase shift is located in a position where $0.2 \leq Ls/L \leq 0.4$ is obtained. Further, the product of a coupling factor κ and a cavity length L, that is, κL, is set to the range of $2 \leq \kappa L \leq 4$. The laid-open patent publication states that, when measurement was effected through use of an element having a cavity length of 300 μm, superior single-mode oscillation was ascertained to arise even at a κL value of about 3, and good current-light output was obtained.

Replace the paragraph beginning at page 3, line 21, with:

Japanese Patent Application Laid-Open No. Hei. 6-204607 describes an improvement in the yield and efficiency of a DFB semiconductor laser, including an analog modulation distortion characteristic and a single-mode characteristic. In order to obtain a low-cost, low-distortion analog modulation DFB semiconductor laser, there is employed a structure wherein the reflectance of the front end face of the cavity is less than 5% and wherein the product of a coupling factor κ and a cavity length L, that is, κL, is set to the range of $0.4 \leq \kappa L \leq 1.0$.

Replace the paragraph beginning at page 3, line 30, with:

Further, the related-art $\lambda/4$ phase-shifted DFB semiconductor laser element has encountered difficulty in achieving compatibility of high stability of single mode, a high-yield characteristic, and a high efficiency-and-output characteristic. For this reason, Japanese Patent Application Laid-Open No. Hei. 11-68220 describes a DFB semiconductor laser, wherein a low-reflection film is formed on an optical output end face and wherein a high-reflection film is formed on the other end face. Further, a diffraction grating is formed in a part of the element in the direction toward the cavity. The length of an area where the diffraction grating is to be fabricated is set to 52% to 64% the element length. The product of a coupling factor of the diffraction grating and the length of the diffraction grating fabrication area is set to the range of 0.8 to 2.

Replace the paragraph beginning at page 5, line 9, with:

On pp. 89 to 90, 2000 IEEE 17TH International Semiconductor Laser Conference 25 to 28 September 2000 Hyatt Monterey, Monterey Ca, CONFERENCE DIGEST P13, G. Sakaino *et al.* reported a phase-shifted DFB semiconductor laser. The laser has an active layer made of InGaAsP-based material, a cavity length as short as 200 μm, and a diffraction grating having a high κL value. An active layer of the laser does not have any function of a diffraction grating. In relation to the laser, the relaxation oscillation frequency remains at a value of 12.0 GHz or thereabouts.

Replace the paragraph beginning at page 5, line 22, with:

In order to achieve a transmission rate of 10 Gb/s, a relaxation oscillation frequency of 30 GHz or more is desired. However, it is empirically seen that, if a relaxation oscillation frequency of 15 GHz or more is not obtained, a sufficient eye-pattern opening will not be obtained, thus inducing non negligible deterioration in receiving sensitivity.

Replace the paragraph beginning at page 5, line 28, with:

Moreover, IEEE PHOTONICS TECHNOLOGY LETTERS, VOL. 7, NO. 10, OCTOBER 1995, PP. 1119 to 1121 reports a multiple reflection short-length cavity of active layer isolation type having a λ/4 phase-shifted structure.

Replace the paragraph beginning at page 7, line 24, with:

Fig. 5 is a graph showing the dependence on the length L of the diffraction grating region of the relaxation oscillation frequency fr using as a parameter the coupling coefficient κ of the semiconductor laser according to an embodiment of the present invention.

IN THE CLAIMS

Replace the indicated claims with:

1. (Amended) A semiconductor laser device comprising:

a semiconductor substrate of a first conductivity type;

a first cladding layer of the first conductivity type disposed on the semiconductor substrate;

an active layer disposed on the first cladding layer and having uniformly flat upper and lower boundary surfaces in an optical waveguide direction;

a second cladding layer of a second conductivity type disposed on the active layer; and

a diffraction grating layer having a phase-shifted structure in the optical waveguide direction, between the active layer and one of the first and second cladding layers, wherein

the diffraction grating layer has a length in the optical waveguide direction $L \leq 260\ \mu m$;

a mean coupling factor κ of a diffraction grating layer is $\kappa \geq 150\ cm^{-1}$; and

κL satisfies $5.6 > \kappa L > 3.0$.

2. (Amended) The semiconductor laser device according to claim 1, wherein power threshold gain αth per unit length in a principal axial mode satisfies $7\ cm^{-1} \leq \alpha th \leq 51\ cm^{-1}$.

3. (Amended) The semiconductor laser device according to claim 1, further comprising a heavily-doped p-type region having a carrier concentration of $10^{18}\ cm^{-3}$ in at least a portion of a p-type layer proximate at least a portion of the active layer.

4. (Amended) The semiconductor laser device according to claim 2, further comprising a heavily-doped p-type region having a carrier concentration of $10^{18}\ cm^{-3}$ in at least a portion of a p-type layer proximate at least a portion of the active layer.

5. (Amended) The semiconductor laser device according to claim 1, wherein

$\lambda p - 100 \leq \lambda g \leq \lambda p + 100,$

where a composition wavelength of the diffraction grating layer is λg (nm) and an oscillation wavelength is λp (nm).

6. (Amended) The semiconductor laser device according to claim 2, wherein

$\lambda p - 100 \leq \lambda g \leq \lambda p + 100,$

where a composition wavelength of the diffraction grating layer is λg (nm) and an oscillation wavelength is λp (nm).

7. (Amended) The semiconductor laser device according to claim 3, wherein

$\lambda p - 100 \leq \lambda g \leq \lambda p + 100,$

where a composition wavelength of the diffraction grating layer is λg (nm) and an oscillation wavelength is λp (nm).

8. (Amended) The semiconductor laser device according to claim 4, wherein

$\lambda p - 100 \leq \lambda g \leq \lambda p + 100,$

where a composition wavelength of the diffraction grating layer is λg (nm) and an oscillation wavelength is λp (nm).

9. (Amended) The semiconductor laser device according to claim 1, wherein a highly-refractive portion of the diffraction grating layer has a length longer than that of a low-refractive portion of the diffraction grating layer in the optical waveguide direction.

10. (Amended) The semiconductor laser device according to claim 2, wherein a highly-refractive portion of the diffraction grating layer has a length longer than that of a low-refractive portion of the diffraction grating layer in the optical waveguide direction.

11. (Amended) The semiconductor laser device according to claim 3, wherein a highly-refractive portion of the diffraction grating layer has a length longer than that of a low-refractive portion of the diffraction grating layer in the optical waveguide direction.

12. (Amended) The semiconductor laser device according to claim 4, wherein a highly-refractive portion of the diffraction grating layer has a length longer than that of a low-refractive portion of the diffraction grating layer in the optical waveguide direction.

13. (Amended) The semiconductor laser device according to claim 5, wherein a highly-refractive portion of the diffraction grating layer has a length longer than that of a low-refractive portion of the diffraction grating layer in the optical waveguide direction.

14. (Amended) The semiconductor laser device according to claim 6, wherein a highly-refractive portion of the diffraction grating layer has a length longer than that of a low-refractive portion of the diffraction grating layer in the optical waveguide direction.

15. (Amended) The semiconductor laser device according to claim 7, wherein a highly-refractive portion of the diffraction grating layer has a length longer than that of a low-refractive portion of the diffraction grating layer in the optical waveguide direction.

16. (Amended) The semiconductor laser device according to claim 8, wherein a highly-refractive portion of the diffraction grating layer has a length longer than that of a low-refractive portion of the diffraction grating layer in the optical waveguide direction.

IN THE ABSTRACT

Replace the abstract with:

ABSTRACT OF THE DISCLOSURE

An n-InP second upper cladding layer is laid on a p-InP lower cladding layer while an active layer having upper and lower boundary surfaces that are uniformly flat in an optical waveguide direction is interposed therebetween. A diffraction layer having a

phase-shifted structure in the optical waveguide direction is interposed between the lower cladding layer and the active layer or between the second upper cladding layer and the active layer. The length L of the diffraction grating layer in the direction of the optical waveguide is $L \leq 260$ μm; a mean coupling factor κ of a diffraction grating layer is $\kappa \geq 150$ cm^{-1}; and κL satisfies $5.6 > \kappa L > 3.0$.

REMARKS

The foregoing amendments are made to correct minor translational errors and to meet United States requirements as to form. No new matter is added.

Respectfully submitted,

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AMENDMENTS TO SPECIFICATION, CLAIMS, AND ABSTRACT MADE VIA PRELIMINARY AMENDMENT

Amendments to the paragraph beginning at page 1, line 5:

The present invention relates to a semiconductor laser device, and, more particularly, to a semiconductor laser device having a diffraction grating layer ~~of~~ with a phase shift structure used for optical communication.

Amendments to the paragraph beginning at page 1, line 14:

A distributed feedback semiconductor laser having a diffraction grating provided in the direction of an optical waveguide effects optical feedback corresponding to the period of the diffraction grating, thus enabling single-mode emission. ~~Then~~Thus, the distributed feedback semiconductor laser has been developed ~~for~~ for optical communication.

Amendments to the paragraph beginning at page 1, line 20:

Japanese Patent Application Laid-Open No. Hei. 1-155677~~/1989~~ describes an invention pertaining to a distributed feedback (DFB) semiconductor laser. In relation to a related-art DFB semiconductor laser, the positional relationship between reflection surfaces provided at both ends of the laser in the direction of an optical waveguide and the phase of the diffraction grating affects an oscillation characteristic ~~of~~ having a single longitudinal mode. For this reason, a λ/4 phase-shifted structure has been employed, and both end surfaces of the laser are covered with a non-reflection coating, thereby minimizing the reflectance of the end faces. If the product of a coupling factor κ and a cavity length L~~;~~, that is, κL, is not in the vicinity of a value of 1.25, an axial hole burning phenomenon arises, and, in turn, deteriorates a single longitudinal mode characteristic of the laser. In order to solve the problem, there is described a DFB semiconductor laser, in which the reflectance of optical power of one end surface is set to 30% and the reflectance of the other end is set to 5 to 15%, thereby achieving a κL value of $0.4 \leq \kappa L \leq 1.3$.

Amendments to the paragraph beginning at page 2, line 5:

The related-art DFB semiconductor laser induces an axial hole burning phenomenon when the product of a coupling factor κ and a cavity length L~~;~~, that is, κL, is not in the vicinity of a value of 1.25, thus deteriorating a single longitudinal mode characteristic of the laser. A high-precision, non-reflection coating technique has been pursued, and there has been devised a window structure for embedding end-face sections of a waveguide for minimizing the reflectance of the end faces. In light of the above-described drawbacks, Japanese Patent Application Laid-Open No. Hei. 2-20087~~/1990~~ describes a DFB semiconductor laser which is comparatively easy to manufacture and ~~is of~~ has a structure capable of realizing a single longitudinal mode at high yield. The DFB semiconductor laser has one or more phase shift regions within 20% of the resonance length with reference to the center of the cavity. The reflectance of respective end faces is set to 5 to 15%, and the product κL is set to the range of $0.6 \leq \kappa L \leq 1.0$.

Amendments to the paragraph beginning at page 2, line 20:

In relation to the related-art DFB semiconductor laser, the diffraction grating is adjusted such that the product of a coupling factor κ and a cavity length L~~;~~, that is, κL, assumes a value of 1.2 to 1.3. However, such a semiconductor laser involves a high oscillation threshold current and it tends to saturate in optical output more than other DFB semiconductor lasers under high-temperature operation. To solve the problem, Japanese Patent Application Laid-Open No. Hei. 2-90688~~/1990~~ describes a $\lambda/4$ phase-shifted DFB semiconductor laser. In relation to the laser, an optical guide layer is provided between an active layer and a cladding layer, wherein the thickness of the optical guide layer changes at a period which is an~~ integral~~ integer multiple of half the wavelength of traveling light. Further, the energy gap of the optical guide layer is greater than that of the active layer and smaller than that of the cladding layer. The product of a coupling factor κ and a cavity length L~~;~~, that is, κL, is set to a value of 1.5 to 2.5.

Amendments to the paragraph beginning at page 3, line 3:

In relation to the related-art DFB semiconductor laser, a multilayer dielectric film is formed on an output end face of the laser, thereby reducing optically-induced return noise. This also drastically reduces optical output from the output end face. In order to reduce the optically-induced return noise and to ensure sufficient optical output, Japanese Patent Application Laid-Open No. Hei. 5-48197/~~1993~~ describes a $\lambda/4$ phase-shifted DFB semiconductor laser which is constructed as follows. Namely, the output end face of the laser is covered with a non-reflective coating. Provided that a length from a rear end face to a $\lambda/4$ phase shift point is taken as Ls and the length of a laser cavity is taken as L, $\lambda/4$ phase shift is located in a position where $0.2 \leq Ls/L \leq 0.4$ is obtained. Further, the product of a coupling factor κ and a cavity length L~~;~~, that is, κL, is set to the range of $2 \leq \kappa L \leq 4$. The laid-open patent publication states that, when measurement was effected through use of an element having a cavity length of 300 μm, superior single-mode oscillation was ascertained to arise even at a κL value of about 3, and good current-light output was

obtained.

Amendments to the paragraph beginning at page 3, line 21:

Japanese Patent Application Laid-Open No. Hei. 6-204607~~/1994~~ describes an improvement in the yield and efficiency of a DFB semiconductor laser, including an analog modulation distortion characteristic and a single-mode characteristic. In order to obtain a low-cost, low-distortion analog modulation DFB semiconductor laser, there is employed a structure wherein the reflectance of the front end face of the cavity is less than 5% and wherein the product of a coupling factor κ and a cavity length L~~;~~, that is, κL, is set to the range of $0.4 \leq \kappa L \leq 1.0$.

Amendments to the paragraph beginning at page 3, line 30:

Further, the related-art λ/4 phase-shifted DFB semiconductor laser element has encountered difficulty in achieving compatibility ~~among~~ of high stability of single mode, a high-yield characteristic, and a high efficiency-and-output characteristic. For this reason, Japanese Patent Application Laid-Open No. Hei. 11-68220~~/1999~~ describes a DFB semiconductor laser, wherein a low-reflection film is formed on an optical output end face and wherein a high-reflection film is formed on the other end face. Further, a diffraction grating is formed in a part of the element in the direction toward the cavity. The length of an area where the diffraction grating is to be fabricated is set to 52% to 64% the element length. The product of a coupling factor of the diffraction grating and the length of the diffraction grating fabrication area is set to the range of 0.8 to 2.

Amendments to the paragraph beginning at page 5, line 9:

On pp. 89 to 90, 2000 IEEE 17TH International Semiconductor Laser Conference 25 to 28 September 2000 Hyatt Monterey, Monterey Ca, CONFERENCE DIGEST P13, G. Sakaino *et al.* reported a phase-shifted DFB semiconductor laser. The laser has an active layer made of ~~InGaASP~~ InGaAsP-based material, a cavity length as short as 200

μm, and a diffraction grating ~~of~~ having a high κL value. An active layer of the laser does not have any function of a diffraction grating. In relation to the laser, the relaxation oscillation frequency remains at a value of 12.0 GHz or thereabouts.

Amendments to the paragraph beginning at page 5, line 22:

In order to achieve a transmission rate of 10 Gb/s, ~~acquisition of~~ a relaxation oscillation frequency of 30 GHz or more is desired. However, it is empirically seen that, if a relaxation oscillation frequency of 15 GHz or more is not obtained, a sufficient eye-pattern opening will not be obtained, thus inducing non_negligible deterioration in receiving sensitivity.

Amendments to the paragraph beginning at page 5, line 28:

Moreover, IEEE PHOTONICS TECHNOLOGY LETTERS, VOL. 7, NO. 10, OCTOBER 1995, PP. 1119 to 1121 ~~states~~ reports a multiple reflection short-length cavity of active layer isolation type having a $\lambda/4$ phase-shifted structure.

Amendments to the paragraph beginning at page 7, line 24:

Fig. 5 is a graph showing the dependence~~,~~ on the length L of the diffraction grating region~~,~~ of the relaxation oscillation frequency fr using as a parameter the coupling coefficient κ of the semiconductor laser according to an embodiment of the present invention.

Amendments to the existing claims:

1. (Amended) A semiconductor laser device comprising:

a semiconductor substrate of a first conductivity type;

a first cladding layer of the first conductivity type ~~provided~~ disposed on the semiconductor substrate;

an active layer ~~provided~~ disposed on the first cladding layer and having uniformly flat upper and lower boundary surfaces in ~~the direction of~~ an optical waveguide direction;

a second cladding layer of a second conductivity type ~~provided~~ disposed on the active layer; and

a diffraction grating layer having a phase-shifted structure~~, provided~~ in the ~~direction of the~~ optical waveguide direction, between ~~the first cladding layer and~~ the active layer ~~or between~~ and one of the first and second cladding ~~layer and the active layer~~ layers, wherein

~~the length L of~~ the diffraction grating layer has a length in the ~~direction of the~~ optical waveguide ~~is taken as~~ direction $L \leq 260$ μm;

a mean coupling factor κ of a diffraction grating layer is ~~taken as~~ $\kappa \geq 150$ cm^{-1}; and

~~a value~~ κL~~, which is the product of the length L and the mean coupling factor κ, is taken as~~ satisfies $5.6 > \kappa L > 3.0$.

2. (Amended) The semiconductor laser device according to claim 1, wherein ~~the~~ power threshold gain αth per unit length in a principal axial mode ~~is set to~~ satisfies $7\ cm^{-1} \leq \alpha th \leq 51\ cm^{-1}$.

3. (Amended) The semiconductor laser device according to claim 1 ~~or 2~~, further comprising~~:~~ a heavily-doped p-type region ~~doped with p-type impurities at~~ having a carrier concentration of 10^{18} cm^{-3} in at least a portion of a p-type layer ~~of p-conductivity type located~~ proximate ~~to an active layer or~~ at least a portion of the active layer.

4. (Amended) The semiconductor laser device according to claim 2, further comprising~~:~~ a heavily-doped p-type region ~~doped with p-type impurities at~~ having a carrier concentration of 10^{18} cm^{-3} in at least a portion of a p-type layer ~~of p-conductivity type located~~ proximate ~~to an active layer or~~ at least a portion of the active layer.

5. (Amended) The semiconductor laser device according to~~ claims~~ claim 1, wherein~~ there is further achieved~~

$\lambda p - 100 \leq \lambda g \leq \lambda p + 100$,

~~provided that~~where a composition wavelength of the diffraction grating layer is~~ taken as~~ λg (nm) and an oscillation wavelength is~~ taken as~~ λp (nm).

6. (Amended) The semiconductor laser device according to~~ claims~~ claim 2, wherein~~ there is further achieved~~

$\lambda p - 100 \leq \lambda g \leq \lambda p + 100$,

~~provided that~~where a composition wavelength of the diffraction grating layer is~~ taken as~~ λg (nm) and an oscillation wavelength is~~ taken as~~ λp (nm).

7. (Amended) The semiconductor laser device according to~~ claims~~ claim 3, wherein~~ there is further achieved~~

$\lambda p - 100 \leq \lambda g \leq \lambda p + 100$,

~~provided that~~where a composition wavelength of the diffraction grating layer is~~ taken as~~ λg (nm) and an oscillation wavelength is~~ taken as~~ λp (nm).

8. (Amended) The semiconductor laser device according to~~ claims~~ claim 4, wherein~~ there is further achieved~~

$\lambda p - 100 \leq \lambda g \leq \lambda p + 100$,

~~provided that~~where a composition wavelength of the diffraction grating layer is~~ taken as~~ λg (nm) and an oscillation wavelength is~~ taken as~~ λp (nm).

9. (Amended) The semiconductor laser device according to~~ claims~~ claim 1, wherein~~ the length of~~ a highly-refractive portion~~ constituting diffraction grating~~ of the diffraction grating layer~~ is set so as to become~~ has a length longer than that of a low-refractive portion of the diffraction grating layer in the~~ direction of the~~ optical waveguide direction.

10. (Amended) The semiconductor laser device according to ~~claims~~ claim 2, wherein ~~the length of~~ a highly-refractive portion ~~constituting diffraction grating~~ of the diffraction grating layer ~~is set so as to become~~ has a length longer than that of a low-refractive portion of the diffraction grating layer in the ~~direction of the~~ optical waveguide direction.

11. (Amended) The semiconductor laser device according to ~~claims~~ claim 3, wherein ~~the length of~~ a highly-refractive portion ~~constituting diffraction grating~~ of the diffraction grating layer ~~is set so as to become~~ has a length longer than that of a low-refractive portion of the diffraction grating layer in the ~~direction of the~~ optical waveguide direction.

12. (Amended) The semiconductor laser device according to ~~claims~~ claim 4, wherein ~~the length of~~ a highly-refractive portion ~~constituting diffraction grating~~ of the diffraction grating layer ~~is set so as to become~~ has a length longer than that of a low-refractive portion of the diffraction grating layer in the ~~direction of the~~ optical waveguide direction.

13. (Amended) The semiconductor laser device according to ~~claims~~ claim 5, wherein ~~the length of~~ a highly-refractive portion ~~constituting diffraction grating~~ of the diffraction grating layer ~~is set so as to become~~ has a length longer than that of a low-refractive portion of the diffraction grating layer in the ~~direction of the~~ optical waveguide direction.

14. (Amended) The semiconductor laser device according to ~~claims~~ claim 6, wherein ~~the length of~~ a highly-refractive portion ~~constituting diffraction grating~~ of the diffraction grating layer ~~is set so as to become~~ has a length longer than that of a low-refractive portion of the diffraction grating layer in the ~~direction of the~~ optical waveguide direction.

15. (Amended) The semiconductor laser device according to ~~claims~~ <u>claim</u> 7, wherein ~~the length of~~ a highly-refractive portion ~~constituting diffraction grating~~ of the diffraction grating layer ~~is set so as to become~~ <u>has a length</u> longer than that of a low-refractive portion of the diffraction grating layer in the ~~direction of the~~ optical waveguide <u>direction</u>.

16. (Amended) The semiconductor laser device according to ~~claims~~ <u>claim</u> 8, wherein ~~the length of~~ a highly-refractive portion ~~constituting diffraction grating~~ of the diffraction grating layer ~~is set so as to become~~ <u>has a length</u> longer than that of a low-refractive portion of the diffraction grating layer in the ~~direction of the~~ optical waveguide <u>direction</u>.

Amendments to the abstract:

ABSTRACT OF THE DISCLOSURE

An n-InP second upper cladding layer ~~22~~ is laid on a p-InP lower cladding layer ~~14~~ while an active layer ~~16 whose~~ <u>having</u> upper and lower boundary surfaces <u>that</u> are uniformly flat in ~~the direction of~~ <u>an</u> optical waveguide <u>direction</u> is interposed therebetween. A diffraction layer ~~20~~ having a phase-shifted structure ~~provided~~ in the ~~direction of~~ optical waveguide <u>direction</u> is interposed between the lower cladding layer ~~14~~ and the active layer ~~16,~~ or between the second upper cladding layer ~~22~~ and the active layer ~~16~~. The length L of the diffraction grating layer ~~20~~ in the direction of ~~an~~ <u>the</u> optical waveguide is ~~taken as~~ $L \leq 260$ μm; a mean coupling factor κ of a diffraction grating layer is ~~taken as~~ $\kappa \geq 150$ cm^{-1}; and ~~a value~~ κL~~, which is the product of the length L and the mean coupling factor κ, is taken as~~ <u>satisfies</u> $5.6 > \kappa L > 3.0$.

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PENDING CLAIMS AFTER ENTRY OF PRELIMINARY AMENDMENT

1. A semiconductor laser device comprising:

a semiconductor substrate of a first conductivity type;

a first cladding layer of the first conductivity type disposed on the semiconductor substrate;

an active layer disposed on the first cladding layer and having uniformly flat upper and lower boundary surfaces in an optical waveguide direction;

a second cladding layer of a second conductivity type disposed on the active layer; and

a diffraction grating layer having a phase-shifted structure in the optical waveguide direction, between the active layer and one of the first and second cladding layers, wherein

the diffraction grating layer has a length in the optical waveguide direction $L \leq 260$ µm;

a mean coupling factor κ of a diffraction grating layer is $\kappa \geq 150$ cm^{-1}; and κL satisfies $5.6 > \kappa L > 3.0$.

2. The semiconductor laser device according to claim 1, wherein power threshold gain αth per unit length in a principal axial mode satisfies 7 cm^{-1} $\leq \alpha th \leq$ 51 cm^{-1}.

3. The semiconductor laser device according to claim 1, further comprising a heavily-doped p-type region having a carrier concentration of 10^{18} cm^{-3} in at least a portion of a p-type layer proximate at least a portion of the active layer.

4. The semiconductor laser device according to claim 2, further comprising a heavily-doped p-type region having a carrier concentration of 10^{18} cm^{-3} in at least a portion of a p-type layer proximate at least a portion of the active layer.

5. The semiconductor laser device according to claim 1, wherein

$\lambda p - 100 \leq \lambda g \leq \lambda p + 100$,

where a composition wavelength of the diffraction grating layer is λg (nm) and an oscillation wavelength is λp (nm).

6. The semiconductor laser device according to claim 2, wherein

$\lambda p - 100 \leq \lambda g \leq \lambda p + 100$,

where a composition wavelength of the diffraction grating layer is λg (nm) and an oscillation wavelength is λp (nm).

7. The semiconductor laser device according to claim 3, wherein

$\lambda p - 100 \leq \lambda g \leq \lambda p + 100$,

where a composition wavelength of the diffraction grating layer is λg (nm) and an oscillation wavelength is λp (nm).

8. The semiconductor laser device according to claim 4, wherein

$\lambda p - 100 \leq \lambda g \leq \lambda p + 100$,

where a composition wavelength of the diffraction grating layer is λg (nm) and an oscillation wavelength is λp (nm).

9. The semiconductor laser device according to claim 1, wherein a highly-refractive portion of the diffraction grating layer has a length longer than that of a low-refractive portion of the diffraction grating layer in the optical waveguide direction.

10. The semiconductor laser device according to claim 2, wherein a highly-refractive portion of the diffraction grating layer has a length longer than that of a low-refractive portion of the diffraction grating layer in the optical waveguide direction.

11. The semiconductor laser device according to claim 3, wherein a highly-refractive portion of the diffraction grating layer has a length longer than that of a low-refractive portion of the diffraction grating layer in the optical waveguide direction.

12. The semiconductor laser device according to claim 4, wherein a highly-refractive portion of the diffraction grating layer has a length longer than that of a low-refractive portion of the diffraction grating layer in the optical waveguide direction.

13. The semiconductor laser device according to claim 5, wherein a highly-refractive portion of the diffraction grating layer has a length longer than that of a low-refractive portion of the diffraction grating layer in the optical waveguide direction.

14. The semiconductor laser device according to claim 6, wherein a highly-refractive portion of the diffraction grating layer has a length longer than that of a low-refractive portion of the diffraction grating layer in the optical waveguide direction.

15. The semiconductor laser device according to claim 7, wherein a highly-refractive portion of the diffraction grating layer has a length longer than that of a low-refractive portion of the diffraction grating layer in the optical waveguide direction.

16. The semiconductor laser device according to claim 8, wherein a highly-refractive portion of the diffraction grating layer has a length longer than that of a low-refractive portion of the diffraction grating layer in the optical waveguide direction.